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ABSTRACT

This curriculum outline consists of behavioral objectives (called terminal and enabling objectives) for Introduction to Engineering Chemistry, a one-semester, post-secondary course consisting of four 1-hour lectures each week. Course goal is to introduce marine engineering students to the rudiments of basic/introductory inorganic chemistry. The following subject areas (units) are considered in the course: fundamental concepts; structure of the atom and the periodic law; the relationship of periodic classification to the properties of the elements; general principles of chemical bonding; chemical symbols, formulae, and equations; the gaseous state and kinetic molecular theory; gram molecular volume of gases and molecular, atomic, and equivalent weights; liquid and solid states; solutions; solutions of electrolytes; oxidation-reduction reactions; acids, bases, and salts; chemical equilibria; ionic equilibria involving weak electrolytes; solubility product principle; electrochemistry; chemistry and properties of liquefied natural gas; alloys; and nuclear chemistry. Each unit is numbered (from 1 to 19), with terminal objectives taking on the number of a given unit. Enabling objectives are assigned both unit and terminal objective numbers. (JN)

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CURRICULUM OUTLINE

for

INTRODUCTION TO ENGINEERING CHEMISTRY

(First Edition)
(Review Cycle-Annual)

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INTRODUCTION: Curriculum outlines provide instructors, among other things, with overviews of what students should be able to demonstrate when they have completed a course, a unit of instruction, or perhaps, even a lesson. These behaviors are called terminal and enabling objectives. They are the objectives over which students in one way or another are tested to determine whether they can demonstrate minimum levels of competency as set forth by course instructors. Terminal objectives are somewhat broad in scope when compared with enabling objectives. Enabling objectives as their name suggests are the objectives with which, when students demonstrate competency, allow teachers to decide to what degree their students are competent with a terminal objective. To be competent, with a terminal objective, however, does not mean students must demonstrate competency with every enabling objective of a specific terminal objective. The actual number of enabling objectives over which students must show facility is set by the course instructor and constitutes a performance standard or criterion. For example, it may be that the minimum competency level for a certain terminal objective is 70%. This may translate to students having to show facility with 70% of the enabling objectives for that erminal objective. The percentage may change from one to another terminal objective.

The curriculum outline has been divided into units, each numbered successively from 1.0 to the end. Each unit may involve one or more lectures, a matter of instructor style, desires and the like. Terminal objectives take on the numbers of the units, 1 to as many as there are, followed by successive numerals in the tenths place (for example, 1.1, 1.2, 1.3). In the example, unit 1 has 3 terminal objectives. Enabling objectives take on the number of the unit, then the

number of the terminal objective followed by the numbering in the hundredths place from 1 to the end (for example, 1.1.1, 1.1.2, 1.1.3, 2.1.1, 2.1.2, 2.2.1, 2.2.2).

MISSION: Introduction to Engineering Chemistry is a four semester hour (one semester) post secondary course consisting of four one hour lectures each week. Its companion, Introduction to Engineering Chemistry Laboratory is a separate one semester hour course (two hours each week). Assumptions are not made regarding the background of entering students. High school chemistry is not a prerequisite for this course. The mission of the course is to introduce marine engineering students to the rudiments of basic or introductory inorganic chemistry. Special topics, when taken up, are engineering oriented to the extent the theory involved may, with a relative degree of ease, be applied to the marine world of shipping and further the marine environment and its effects upon ship hulls.

SCOPE: The following subject areas are considered in Introduction to Engineering Chemistry; (1) fundamental concepts; (2) structure of the atom and the periodic law; (3) the relationship of periodic classification to the properties of the elements; (4) general principles of chemical bonding; (5) chemical symbols, formulae and equations; (6) the gaseous state and kinetic molecular theory; (7) gram molecular volume of gases and molecular, atomic and equivalent weights; (8) liquid and solid states; (9) solutions; (10) solutions of electrolytes; (11) oxidation-reduction reactions; (12) acids, bases and salts; (13) chemical equilibra; (14) ionic equilibra involving weak electrolytes; (15) solubility product principle; (16) electrochemistry; (17) chemistry and properties of liquified natural gas; (18) alloys; (19) nuclear chemistry.

TERMINAL AND ENABLING OBJECTIVES: As a result of taking this course and completing the associated activities, students should:

UNIT 1.0 Fundamental Concepts

1.1 KNOW fundamental concepts of science relevant to introductory chemistry.

1.1.1 DEFINE matter and energy.

1.1.2 DESCRIBE the relationships between matter and energy.

1.1.3 DIFFERENTIATE between three states of matter.

1.1.4 DISTINGUISH between elements, compounds and mixtures.

1.1.5 DISTINGUISH between the physical and chemical properties of a substance.

1.1.6 USE the metric system.

1.1.7 LIST the basic metric units and their common prefixes.

1.1.8 CONVERT temperatures between the Fahrenheit, celsius and Kelvin scales.

1.1.9 PERFORM calculations involving density.

1.1.10 DEFINE specific gravity and specific heat.

1.1.11 IDENTIFY the differences between chemical and physical changes.

UNIT 2.0 Structure of the Atom and the Periodic Law

2.1 UNDERSTAND the structure of the atom and its relationship to the periodic law.

2.1.1 GIVE chemical symbols for elements.

2.1.2 DESCRIBE the composition of the atom in terms of protons, neutrons and electrons.

2.1.3 DESCRIBE the approximate size, relative mass and charge of an atom, proton, neutron and electron.

2.1.4 WRITE the symbols for and the charges on positive and negative ions.

2.1.5 DESCRIBE evidence from radioactivity studies that suggests the existence of subatomic particles.

2.1.6 DEFINE atomic number.

2.1.7 DEFINE atomic weight.

2.1.8 RELATE atomic structure to groups and families.

2.1.9 EXPLAIN the Bohr model of the atom in terms of energy levels, line spectra and electronic structure.

2.1.10 RELATE s,p,d sub-orbitals to energy levels.

2.1.11 DESCRIBE shapes of s,p,d, sub-orbitals.

2.1.12 RELATE principle quantum numbers (n) to the periodic table.

2.1.13 RELATE azimuthal quantum numbers (ℓ) to principle quantum numbers.

2.1.14 RELATE magnetic or orientational quantum numbers to azimuthal quantum numbers.

2.1.15 DESCRIBE the filling order of atomic orbitals and sub-orbitals.

2.1.16 RELATE spin quantum numbers to suborbitals.

UNIT 3.0 The Relationship of Periodic Classification to the Properties of Elements

3.1 KNOW the relationships between periodic classification of elements and the properties of the elements.

3.1.1 APPLY the concept of Avagadro's number to elements of different masses.

3.1.2 DEFINE groups in terms of electron configuration.

3.1.3 DEFINE families in terms of electron configuration.

3.1.4 IDENTIFY locations of activite metals, transition elements and nonmetals on the periodic table.

3.1.5 DESCRIBE variations in ionization energies based upon elements positions on the periodic table.

3.1.6 DESCRIBE the relationship between periodic classification of elements and atomic radii.

3.1.7 EXPLAIN the concept of electron affinity and its relationship to ionization energies.

3.1.8 DESCRIBE the relationship between melting point and periodic classification.

3.2 UNDERSTAND the uses of the periodic table.

3.2.1 DESCRIBE the relationship between compound formation and atomic number.

3.2.2 PREDICT diatomic molecule formation based upon atomic number.

UNIT 4.0 General Principles of Chemical Bonding

4.1 KNOW how to apply oxidation numbers in chemical compound formation.

4.1.1 DETERMINE the number of valence electrons of an atom and write a Lewis structure.

4.1.2 WRITE electron configurations for ions.

4.1.3 PREDICT the valence of common nonmetallic elements from their position on the periodic table.

4.1.4 ASSIGN oxidation numbers to ions and molecules.

4.1.5 ASSIGN oxidation numbers to atoms in molecules and ions.

4.2 UNDERSTAND the concept of electronegativity.

4.2.1 EXPLAIN the significance of electronegativity.

4.2.2 RELATE the electronegativity of an element to its position on the periodic table.

4.2.3 PREDICT bond polarities using a table of electronegativities.

4.2.4 COMPARE compounds based upon electronegativities to determine which bonds have more covalent and which bonds have more ionic character.

4.3 UNDERSTAND ionic and covalent bonding.

4.3.1 PREDICT the formation of ionic and covalent bonds (using the periodic table).

4.3.2 DESCRIBE the ionic-covalent bond continuum.

4.3.3 WRITE Lewis structures for compounds containing covalent bonds.

4.3.4 DESCRIBE bonding orbital shapes.

UNIT 5.0 Chemical Symbols, Formulae and Equations

5.1 KNOW general types of chemical changes.

5.1.1 IDENTIFY replacement reactions.

5.1.2 IDENTIFY rearrangement reactions.

5.1.3 IDENTIFY double replacement reactions.

5.1.4 IDENTIFY combination reactions.

5.1.5 DERIVE formulae for replacement, rearrangement and combination reactions.

5.2 UNDERSTAND the significance of Avogadro's number, moles, formula weights and molecular weights in balancing chemical equations.

5.2.1 BALANCE replacement, rearrangement and combination reactions using Avogadro's number.

5.2.2 BALANCE replacement, rearrangement and combination reactions using moles.

5.2.3 DEFINE formula weights.

5.2.4 BALANCE replacement, rearrangement and combination reactions using molecular weights.

5.3 UNDERSTAND percent composition based upon chemical formulae.

5.3.1 SOLVE problems based upon percent composition.

5.4 KNOW how to apply balanced chemical equations to real life situations.

5.4.1 MAKE calculations based upon balanced chemical equations.

UNIT 6.0 The Gaseous State and Kinetic Molecular Theory.

6.1 UNDERSTAND the gaseous state and kinetic molecular theory.

6.1.1 LIST the assumptions upon which the kinetic theory of gases is based.

6.1.2 EXPLAIN the assumptions on which the kinetic theory of gases is based.

6.1.3 COMPARE the general characteristics of gases to other states of matter.

6.1.4 LIST ways in which gases are distinctly different from other states of matter.

6.1.5 LIST the variables required to define the state of a gas.

6.1.6 DEFINE standard temperature and pressure (STP).

6.1.7 CORRECT for the effects of water vapor pressure in calculating the quantity of a gas collected over water.

6.1.8 EXPLAIN the concept of gas density.

6.1.9 DESCRIBE how gas density is related to temperature pressure and molecular weight.

6.1.10 APPLY boyle's law to the solution of problems.

6.1.11 APPLY Charle's law to solution problems.

6.1.12 DESCRIBE Graham's law.

6.1.13 APPLY Avogadro's hypothesis to the solution of problems.

6.1.14 CALCULATE molecular weight, given gas density under defined conditions of temperature and pressure.

6.1.15 CALCULATE gas density under stated conditions, given molecular weight.

6.1.16 DESCRIBE how gas molecules are distributed over a range of speeds.

6.1.17 DESCRIBE how gas molecule distribution changes with temperature.

6.1.18 EXPLAIN the correction terms to P and V that appear in the Van der Walls equation of state for a gas.

6.1.19 EXPLAIN the concept of mean free path.

6.1.20 EXPLAIN how the concept of mean free path relates to the diffusion rates of molecules in the gaseous state.

6.1.21 DESCRIBE the relationship between mean free path and thermal conductivity.

UNIT 7.0 Gram Molecular Volume of Gases and Molecular, Atomic and Equivalent Weights

7.1 UNDERSTAND gram-molecular volume of gases in terms of molecular, atomic and equivalent weights.

7.1.1 EXPLAIN the way in which pressure, volume and temperature are related in the ideal gas equation.

7.1.2 EXPLAIN the origin of deviations shown by real gases from the relationship PV/RT=1 for a mole of ideal gas.

7.1.3 LIST two factors responsible for deviations of gas from ideal behavior.

7.1.4 DERIVE atomic weights from specific heats of gases.

7.1.5 DESCRIBE the relationship between atomic weights and equivalent weights.

UNIT 8.0 The Liquid and Solid States

8.1 KNOW the differences between liquids and solids and how they react under different conditions.

8.1.1 DISTINGUISH between liquids and solids on a molecular level.

8.1.2 EXPLAIN the properties of each phase (surface tension, viscosity, vapor pressure, boiling point, melting point) using kinetic-molecular theory and the concept of intermolecular attractions.

8.1.3 DISTINGUISH between crystalline and amorphos solids.

8.1.4 EXPLAIN the nature of equilibria that may exist between phases.

8.1.5 ACCOUNT for enthalpy changes that accompany phase changes.

8.1.6 DESCRIBE the relationship between pressure, vapor pressure, temperature and boiling point.

8.1.7 DEFINE Critical temperature.

8.1.8 DEFINE critical pressure.

8.1.9 ACCOUNT for differences in critical temperature and pressure of different substances based upon intermolecular forces.

8.1.10 CALCULATE the density of a substance from the number of particles per unit cell.

8.1.11 EXPLAIN the various types of intermolecular forces.

8.1.12 DRAW phase diagrams.

8.1.13 USE phase diagrams to predict phases present at specific temperatures and pressures.

UNIT 9.0 Solutions

9.1 UNDERSTAND the definition of solution.

9.1.1 DEFINE gas-liquid solutions.

9.1.2 DEFINE liquid-liquid solutions.

9.1.3 DEFINE solid-liquid solutions.

9.1.4 DEFINE solvent.

9.1.5 DEFINE solute.

9.1.6 CALCULATE concentration in molarity, molality, normality, mole fraction and weight percent.

9.1.7 CONVERT concentrations in one type unit to another type unit (e.g. molarity → normality, etc.)

9.1.8 DESCRIBE dilute solutions.

9.1.9 DESCRIBE concentrated solutions.

9.1.10 DEFINE unsaturated, saturated, and supersaturated solutions.

9.1.11 DESCRIBE the difference between a colloid and a true solution.

9.2 KNOW the effects of solutes upon the properties of the solvent.

9.2.1 DESCRIBE the solution process including bonds made and broken when a substance dissolves.

9.2.2 EXPLAIN energy changes occurring in the solution process in terms of solvent-solute forces.

9.2.3 APPLY LaChatelier's principle to account for the effects of temperature and pressure upon solubilities.

9.2.4 DESCRIBE the effect of solute concentration upon solvent vapor pressure.

UNIT 10.0 Solutions of Electrolytes

10.1 UNDERSTAND the meaning of solutions of electrolytes.

- 10.1.1 PREDICT whether a substance is or is not an electrolyte.
- 10.1.2 DETERMINE whether substances are strong or weak electrolytes.
- 10.1.3 EXPLAIN the difference between the magnitude of changes in colligative properties caused by electrolytes as compared to those caused by nonelectrolytes.
- 10.1.4 IDENTIFY the properties of ionic compounds and solutions.
- 10.1.5 DESCRIBE the dissolution mechanism for ionic compounds.
- 10.1.6 DESCRIBE the way in which molecular solids dissolve.

UNIT 11.0 Oxidation-Reduction Reactions

11.1 KNOW definitions of terms related to oxidation-reduction reactions.

- 11.1.1 DEFINE oxidation.
- 11.1.2 DEFINE reduction.
- 11.1.3 DEFINE oxidizing agent.
- 11.1.4 DEFINE reducing agent.
- 11.1.5 IDENTIFY the oxidizing agent.
- 11.1.6 IDENTIFY the reducing agent.
- 11.1.7 RECOGNIZE redox reactions.
- 11.1.8 EXPLAIN how gram-equivalent weights relate to oxidizing and reducing agents.

11.2 UNDERSTAND how to balance oxidation-reduction reactions.

- 11.2.1 BALANCE redox equations using by the change in oxidation number method.
- 11.2.2 BALANCE redox equations by the ion-electron method.
- 11.2.3 BALANCE redox reactions using the half reaction method.
- 11.2.4 DESCRIBE the steps used in balancing reactions by the algebraic method.

UNIT 12.0 Acids, Bases and Salts

12.1 KNOW the properties of acids, bases and salts.

12.1.1 DESCRIBE the effect of an acid on the solvent.

12.1.2 DESCRIBE the effect of a base on a solution.

12.1.3 IDENTIFY the source of a salt in an acid base reaction.

12.1.4 EXPLAIN the meaning of acid-base neutralization.

12.1.5 EXPLAIN the process that occurs when an acid dissolves in water.

12.1.6 DESCRIBE the forms in which the proton exists in water.

12.1.7 DEFINE autoionization.

12.1.8 WRITE an ion product constant for autoionization.

12.1.9 DEFINE pH.

12.1.10 CALCULATE pH for a given (OH^-).

12.1.11 DEFINE pOH.

12.1.12 CALCULATE pH from a given (OH^-).

12.1.13 DEFINE strong acid.

12.1.14 DEFINE strong base.

12.1.15 CALCULATE Ka.

12.1.16 CALCULATE Kb.

12.1.17 WRITE the acid-dissociation constant expression for a weak acid in water.

12.1.18 WRITE the base dissociation constant for a weak base in water.

12.1.19 DEFINE conjugate acid.

12.1.20 DEFINE conjugate base.

12.2 KNOW acid-base theories.

12.2.1 DEFINE acid, base, conjugate acid and conjugate base in terms of the Bronstead-Lowry theory.

12.2.2 DEFINE acid and base in terms of the Lewis theory.

UNIT 13.0 Chemical Equilibrium

13.1 UNDERSTAND the factors affecting reaction rates.

- 13.1.1 EXPLAIN how concentration affects reaction rate.
- 13.1.2 DESCRIBE how temperature affects reaction rate.
- 13.1.3 EXPLAIN the collision theory of reaction rates.
- 13.1.4 DESCRIBE the meaning of slowest step in reaction mechanisms.
- 13.1.5 DEFINE calalyst.
- 13.1.6 EXPLAIN how pressure affects reaction rates.

13.2 UNDERSTAND the meaning of equilibrium constants.

- 13.2.1 EXPLAIN how LeChatelier's principle is related to chemical equilibrium.
- 13.2.2 WRITE the equilibrium constant expression for a balanced chemical equation.
- 13.2.3 CALCULATE Kc.
- 13.2.4 CALCULATE Kp.
- 13.2.5 CALCULATE the reaction quotient, Q.
- 13.2.6 CALCULATE equilibrium concentrations.

UNIT 14.0 Ionic Equilibria Involving Weak Electrolytes

14.1 UNDERSTAND the meaning of ionic equilibria.

- 14.1.1 DEFINE common ion effect.
- 14.1.2 CALCULATE the effect of an added common ion on the solubility of a slightly soluble salts.
- 14.1.3 DESCRIBE how complex formation can affect the solubility of slightly soluble salts.
- 14.1.4 EXPLAIN the effect of pH on a solubility equilibrium involving a basic or acidic ion.
- 14.1.5 CALCULATE ion product constants of weak acids and bases.

14.1.6 CALCULATE pH at any point on a titration curve.

14.1.7 DESCRIBE how a buffer solution operates to control pH.

14.1.8 DESCRIBE titration curves for titration of weak acid by a strong base and a weak base by a strong acid.

14.1.9 DESCRIBE how a buffer solution is made.

UNIT 15.0 The Solubility Product Principle

15.1 UNDERSTAND the solubility product principle.

15.1.1 CALCULATE K_{sp} from molar solubilities.

15.1.2 CALCULATE molar solubilities from K_{sp}.

15.1.3 MAKE calculations involving precipitation of slightly soluble electrolytes.

UNIT 16.0 Electrochemistry

16.1 KNOW the basic principles of electrochemistry.

16.1.1 DEFINE fundamental electrical units.

16.1.2 DIAGRAM simple voltaic and electrolytic cells.

16.1.3 DESCRIBE Faraday's law and how it relates to electrolysis.

16.1.4 CALCULATE the EMF generated by a voltaic cell.

16.1.5 CALCULATE the minimum EMF required to cause an electrolytic cell reaction to proceed.

16.1.6 USE electrode polentials to predict whether a reaction will be spontaneous.

16.1.7 CALCULATE EMF's using the Nernst equation.

16.1.8 CALCULATE ion concentrations using Nernst equation.

16.1.9 DESCRIBE corrosion.

16.1.10 EXPLAIN the principles underlying cathodic protection.

UNIT 17.0 Chemistry and Properties of Liquified Natural Gas

17.1 KNOW the properties of liquid natural gas.

17.1.1 DESCRIBE the composition of natural gas.

17.1.2 DESCRIBE the liquid ratio of liquid natural gas.

UNIT 18.0 Alloys

18.1 UNDERSTAND the definition of alloy.

18.1.1 DESCRIBE what is meant by alloy.

18.1.2 DEFINE solution alloy.

18.1.3 DEFINE substitutional alloy.

18.1.4 DEFINE interstitial alloy.

18.1.5 DEFINE heterogeneous alloy.

18.1.6 DEFINE intermetallic alloy.

UNIT 19.0 Nuclear Chemistry

19.1 UNDERSTAND the meaning of nuclear chemistry.

19.1.1 WRITE nuclear symbols for protons, neutrons, electrons, alpha particals and positrons.

19.1.2 DETERMINE the effect of different types of decay on the proton-neutron ratio.

19.1.3 PREDICT the type of decay that a nucleus will undergo based on its position relative to the belt of stability.

19.1.4 BALANCE nuclear equations.

19.1.5 USE the half-life of a substance to predict the amount of radioisotope present after a given period.

19.1.6 EXPLAIN the use of radioisotopes in dating.

19.1.7 EXPLAIN detection of radioactivity.

19.1.8 DESCRIBE the basic design of a Geiger counter.

19.1.9 CALCULATE energy or mass change of a reaction using $\Delta E=mc^2$

19.1.10 CALCULATE binding energies of the nuclei.

19.1.11 DEFINE units used to describe radioactivity.

19.1.12 EXPLAIN fission.

19.1.13 EXPLAIN fusion.